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PULSE GENERATOR

MODEL 5-6826P

Serial No. —

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ALFRED ELECTRONICS 897 COMMERCIAL STREET, PALO ALTO, CALIF.

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ADDENDUM SHEET

Model 5-6826P, PZ, PY

Date	Change No.	Effective S/N	Description
2-13-61	10716	17	L-302 changed to .10 mh, was .24 mh C-310 changed to .005 µf, 1 Kv, was .01 µf, 600 v R-344, 100 Ω, ±10%, 1 w added to V306 circuitry
5-5-61	10772	22	C-301, C-302, C-303 starred values.
3-1-62	10920	28	R313 changed to 3.7K, ±10%, 2W; was 3.9K, 10%, 2W

PULSE GENERATOR
MODEL 5-6826P

SPECIFICATIONS

Pulse Output:	300 to 450 volts positive, adjustable by panel control.
Load Current:	250 ma peak.
Pulse Duration:	1 to 12 microseconds, adjustable by panel control.
Rise and Fall Time:	.6 microseconds or less when load capacitance less than 100 mmfd.
Repetition Rate:	Internal, 10 to 10,000 pps adjustable by panel controls. External, 0 to 10,000 pps by application of any positive going signal 20 volts peak or greater.
Sync Output:	+2 volts pulse at start of output pulse. .1 microsecond rise time, .6 microsecond duration.
Connectors:	Sync Out and External Trigger panel BNC receptacles. Pulse Out and Power Input rear barrier terminals.
Power Input:	105 to 125 v, 60 CPS, approximately 200 voltamperes.
Mounting:	Standard 19" rack. Height: 5 1/4". Width: 19". Depth: 14 1/2" from panel, 16" overall.
Finish:	Panel, grey hammertone. Sides, top and bottom, satin aluminum.
Weight:	25 pounds.

SECTION I — GENERAL

DESCRIPTION

The ALFRED Model 5-6826P pulser generator is a convenient source of pulses in the voltage range of 300 to 450 volts. Pulse width is adjustable from 1 to 12 microseconds, and rise and fall time is .5 microseconds or less.

The Model 5-6826P finds particular use as a modulator for the ALFRED Model 5-6826 high power traveling wave tube amplifier.

The instrument is built for mounting in a standard 19" rack.

SECTION II -- THEORY OF OPERATION

GENERAL

The ALFRED Model 5-6826P pulse generator consists of a thyratron repetition rate generator, Schmitt trigger, a one-shot multivibrator, and a bootstrap power amplifier. Internal power supplies are regulated for stable performance.

CIRCUIT DESCRIPTION

Refer to the Schematic Diagram at the end of this Manual.

The internal repetition rate generator employs thyratron V301 as a relaxation oscillator. Repetition rate is determined by the time constant of R308, R309, and either C301, C302, or C303.

V301 cathode voltage slowly drops as either C301, C302, or C303 charges. While the cathode is more positive than the grid the tube is cut off, but when cathode drops to approximately grid potential, V301 fires. The timing capacitor is thereby discharged through the series resistor R304, R305, or R306 and R307 to produce a positive trigger pulse. When capacitor voltage drops sufficiently, V301 extinguishes and the charge interval again starts.

To enable triggering by external waveforms, V302 is employed in a Schmitt trigger circuit. V302A is held cut off by the cathode current of V302B. A positive signal to V302A grid initiates plate current, causing its plate voltage to drop, thereby reducing V302B grid voltage to below cutoff. Cathode current in R313 transfers to that of V302A.

The reverse action occurs when V302A grid volt drops low enough to restore original cutoff condition. Due to the regenerative action, the transfer takes place very rapidly so that current in V302B abruptly changes. This causes a short voltage pulse in L301 suitable for triggering purposes.

The negative pulse formed in L301 when V302B current turns on, is clipped by V303A connected as series diode. The positive pulse, caused by V302B cutoff, triggers the one-shot pulse forming multivibrator involving V303B, V304 and V305. Also, the positive trigger is attenuated by R317 and R318, and brought out to panel SYNC OUT jack.

The multivibrator operates the same as the Schmitt trigger circuit except that capacitor C307 provides coupling between normally cut off V303B and normally conducting V304 and V305 in parallel. Initiation of plate current in V303B by the positive grid trigger drops V304 and V305 grid voltage below cutoff. However, C307 discharges through R319, R321, and R322, returning grid voltage to original value and V304 and V305 back to conduction.

Plate current cutoff of V304 and V305 removes normal bias to V306, provided by drop in R326, causing V306 to conduct heavily and pull its cathode almost up to plate potential. When bias is restored, cathode voltage drops back down to normal value of about +75 volts. In this manner the output pulse is formed for an interval determined by the discharge of C307. Adjustment of R322 sets discharge rate and hence pulse width. The pulse amplitude depends upon plate voltage on V306.

If output pulse is capacitatively coupled to the load, some droop may occur on the top of long pulses. To compensate for this R328 and C310 are provided. Although some loss in amplitude occurs, R328 can be adjusted to give a rising top to the pulse to cancel subsequent droop.

Two regulated power supplies are provided. Each employs a half wave rectifier-filter, triode connected series tubes V309, V311, and a pentode control amplifier V310, V312. Reference voltage for the +150 volt source is provided by V313. The resistance ratio of R339 and R340 determines output voltage. Reference for the +380 to +580 volt supply is provided by the +150 volt supply so that loss of +150 volts will remove the higher voltage. Resistors R341, R342 and R343 determine the higher voltage. Adjustment is provided by R341.

SECTION III -- INSTALLATION AND OPERATION

INSTALLATION

Immediately upon receipt, carefully unpack and inspect the instrument for damage received from transit. Should any be found, follow procedure outlined on "Shipment Damage Claim" page at the end of this Manual.

The instrument is designed for either rack or bench use in normal ambient temperatures. Primary power requirements are 105 to 125 volts, 60 CPS, at approximately 200 volt-amperes. If operation at any other frequency or voltage is contemplated, consult manufacturer.

If the instrument is rack mounted, supports should be provided in the rack to carry the weight of the instrument upon insertion or removal. When operated with ALFRED Model 5-6826 Traveling Wave Tube Amplifier, use the cables provided to connect rear power and pulse output power terminals as indicated on the TW Amplifier interconnection diagram.

For other applications bring AC power to terminals 2 and 3 of TS302. The instrument is supplied with a jumper between 1 and 2; for remote high voltage on-off control, disconnect this jumper and make desired external connection.

SETTING UP PROCEDURE

1. Connect an oscilloscope to rear pulse OUTPUT terminals. SYNC OUT connection may be used to trigger sweep.
2. Turn on AC power.
3. After a few minutes warmup set pulse AMPLITUDE, WIDTH, and REPETITION RATE to desired values.
4. Adjust rear SLOPE COMP control for minimum droop. For this adjustment either connect the oscilloscope directly across load, or when modulating a microwave oscillator or amplifier observe the detected RF pulse.
5. Operation should now be correct.

SECTION IV -- MAINTENANCE

ROUTINE

CAUTION: High voltages exist in this instrument. Observe the utmost care when checking or making repairs.

Routine maintenance need consist only of testing the tubes at regular intervals to detect marginal performance.

TROUBLE SHOOTING

Should a failure occur, follow a logical procedure to locate the cause. Refer, if necessary, to the Theory of Operation Section and the Schematic Diagram included in this Manual. A blown fuse should be replaced with a 3 amp 250 volt type 3AG. Tubes should be observed to determine if heaters are operating and voltage regulator tubes lit. Test tubes if necessary. Check waveforms noted on Schematic Diagram to detect incorrect performance. Observe extreme care to avoid shock or equipment damage.

WARRANTY

All workmanship and materials are guaranteed for one year. Details concerning warranty adjustment are presented on "Shipment Damage Claim" page at end of this Manual.

GENERAL INFORMATION ON TRAVELING-WAVE TUBES

R. A. Huggins*

Engineers who design circuits which use conventional low frequency vacuum tubes usually have at least a speaking acquaintance with their theory of operation. In designing circuits, or in deciding which type of tube to use, careful use is made of the various characteristic curves associated with these tubes. The following discussion will similarly acquaint the applications engineer with the simple theory of the operation of the traveling-wave tube and familarize him with the various characteristic curves which describe its operation.

MICROWAVE AMPLIFICATION

As the microwave region of the radio frequency spectrum came into practical engineering use, devices were needed which could function as better amplifiers and oscillators. Above a few hundred megacycles conventional vacuum tubes no longer amplify properly because the period of one cycle of the radio frequency wave approaches the time it takes the electrons to travel from cathode to anode. As a result the amplification factor of the tube decreases with increasing frequency until no useful gain can be obtained. This is known as the transit time effect.

The first device which served as a practical amplifier above a few hundred megacycles actually made use of the transit time effect. This device, known as a klystron, became useful primarily as an oscillator. The klystron, however, is also capable of acting as an amplifier. Klystron amplifiers are capable of giving high values of amplification, but they have two serious limitations for many applications: They are relatively narrow band devices which usually have no more than a few megacycles bandwidth between half-power points, and tuning the amplifier to different frequencies requires a mechanical adjustment. The klystron is, however, the forerunner of a general class of microwave electron devices which utilize transit time effects in electron beams. This general class of devices includes the traveling-wave tube (TWT).

A klystron is a narrow band device because it involves the use of a very sharply resonant, high-impedance tuned circuit. It is necessary for a klystron to use such a circuit because interaction takes place with the electrons over very short physical distances, and it must develop high electric fields to have efficient interaction with the electrons. It was reasoned, however, that one might obtain a very broadband amplifying device by using a low-impedance, broadband circuit which developed relatively small electric fields that interacted with the electrons over a long physical distance. Such is the basis on which the traveling-wave tube works, and this basic concept led to a wide range of devices which are useful as broadband amplifiers and oscillators in the microwave region.

The traveling-wave tube yields high values

* President, Huggins Laboratories, Inc.

of amplification over wide frequency ranges with no mechanical tuning mechanism or variation of any voltages or currents applied to the tube. Power amplification greater than 10,000 (i.e., 40 db gain) over a 2:1 frequency range has been obtained with this type of tube. The actual number of megacycles covered by such tubes can be a staggering figure. For example, an operating bandwidth of 2000 megacycles has been obtained in one typical tube type; 7000 megacycles has been obtained in another.

Tubes can be designed to emphasize various special characteristics. For instance, tubes are built which have low noise properties, high power output, or controlled variations of gain with frequency. Many special tubes are designed and built for particular applications.

FORWARD-WAVE HELIX TYPE AMPLIFIER

Among the simplest circuit elements which satisfy the broadband low-impedance circuit requirement of the traveling-wave tube is a simple helical transmission line. On this so-called helix, the radio frequency energy essentially travels at the velocity of light along the wire from which the helix is wound. Since the wire and the energy follow this helical path, progress of the energy along the axis of the helix is at some fraction of the velocity of light. This velocity is determined by the geometry of the helix (i.e., circumference and pitch) and by the dielectric loading due to the structure which supports the helix. The fields associated with this "slow-wave" extend outward and inward into the region adjacent to the helix, and it is into this region that electrons are sent to interact with the waves.

If electrons are directed along the axis of the helix at essentially the same velocity as the waves, an interaction between the waves and electrons occurs wherein the electrons become bunched. As the electrons progress along the axis they become packed into tighter and tighter bunches. Simultaneously, the radio frequency fields on the helix increase in magnitude as they progress down its length. The increase in energy of this "growing wave" is just balanced by a decrease in the average kinetic energy of the electrons in the beam. In other words, the electrons, on the average, have been slowed down and have given up just enough energy to account for the increasing energy or power level in the waves on the helix.

In practice, the electron beam is formed by an electron gun and focused down the center of the helix to a collector electrode at the farther end (see Figure 1). The electron beam is maintained in a tight pencil beam throughout the length of the tube by the confining forces of a longitudinal magnetic field which surrounds the tube. Electron velocity is determined by the voltage difference between the cathode in the electron gun and the helix, and this voltage difference is ad-

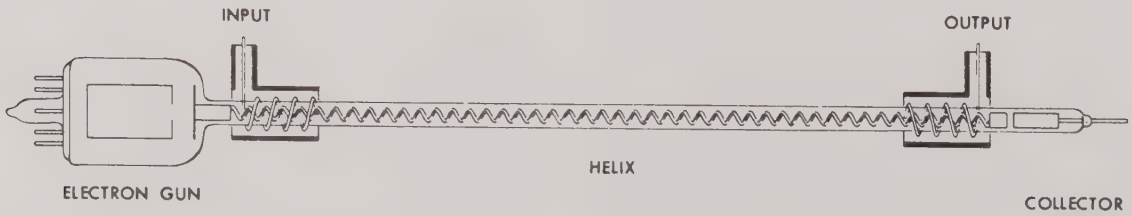


Figure 1. Schematic View of a Traveling-Wave Tube.

justed to give the electrons the right velocity for interaction with the waves. The signal to be amplified is coupled onto the end of the helix nearest the electron gun and propagates along the helix in the same direction as the electron beam. Because of the interaction, the fields on the helix grow exponentially with distance, and these amplified waves are coupled off the helix at the end farthest from the electron gun.

The devices which couple the energy onto and off the helix are special directional couplers which are in themselves helices. These helices are outside the vacuum envelope and are matched to the input and output coaxial transmission lines. This type of coupler is capable of transferring most of the energy from the lines to the main helix, which is inside the vacuum envelope, without making physical contact with the helix. These "coupled helix matches" have the additional advantage of having very wideband transfer characteristic. Further, they are capable of presenting a standing-wave ratio to the coaxial transmission line of 1.5:1 or less.

SPECIFIC CHARACTERISTICS

In the following sections, various characteristic curves that are encountered in traveling-wave tube operation are discussed.

Helix Voltage vs Frequency. A helix is usually designed so that the "slow-waves" travel at a velocity in the range of 1/10 to 1/30 of the velocity of light. If the wave velocity is examined as a function of frequency, it is found that a helix has a general characteristic curve similar to that shown in Figure 2.

In region A, wave velocity varies as a function of frequency; in region B, wave velocity is essentially independent of frequency. A broadband amplifier is normally operated in region B – the "non-dispersive region."

As mentioned before, the electrons must travel at essentially the same velocity as the waves (synchronous velocity) in order to obtain the growing wave interaction. Since the velocity of the wave varies as a function of frequency, the velocity of the electrons must also be varied so that interaction is maintained. Inasmuch as the velocity of the electrons is determined by the voltage difference between the cathode and the helix, there is also a characteristic curve of synchronous helix voltage as a function of frequency (see Figure 2).

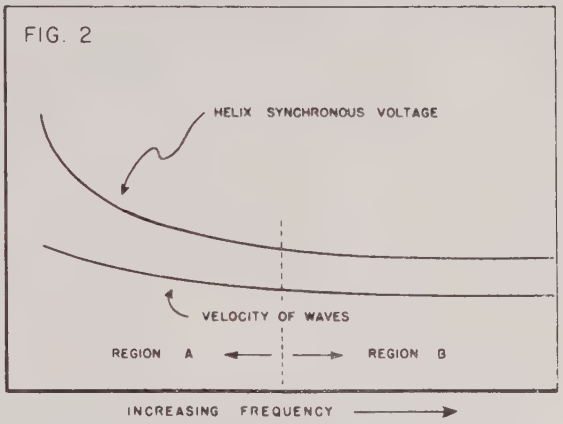


Figure 2. Phase Velocity of the Waves and Synchronous Helix Voltage as a Function of Frequency.

The reason a helix type traveling-wave tube can amplify over wide bandwidths without changing helix voltage can now be easily seen. In the non-dispersive region the synchronous voltage is essentially independent of frequency. That is, the helix voltage which gives the desired interaction between the waves and electrons can be fixed at one value, and this will be the correct value to provide interaction and amplification over a wide range of frequencies.

Gain vs Helix Voltage. To obtain the greatest interaction between the waves and the electrons, and thus the greatest amplification, the helix must be operated at synchronous voltage.

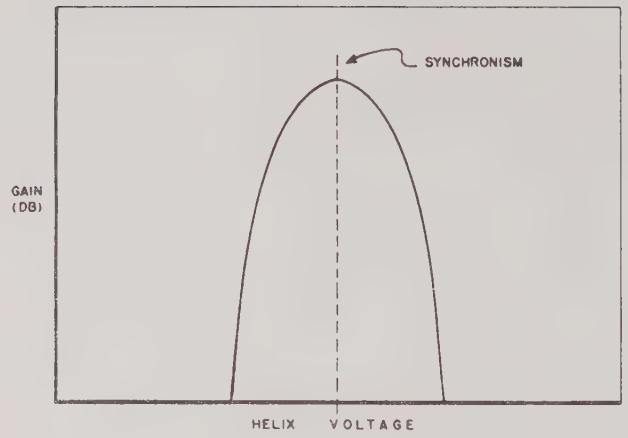


Figure 3. Gain as a Function of Helix Voltage.

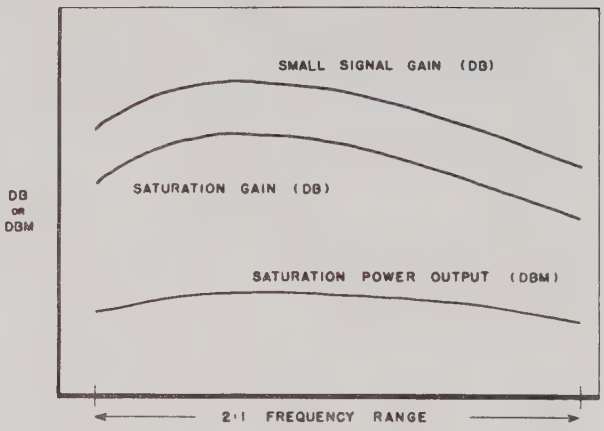


Figure 4. Gain and Power Output as a Function of Frequency.

Should the helix voltage be varied away from synchronism, the gain will decrease as shown by the curve in Figure 3. This characteristic of the TWT is parabolic in shape.

Gain and Power Output vs Frequency. Figure 4 shows a typical plot of gain vs frequency for a fixed value of helix voltage. Small-signal gain is obtained for all values of input signal level except those which drive the tube near its maximum or saturation power output. Saturation gain is the gain obtained when the tube is driven to its saturation power output level. It is seen that the gain and power output curves generally reach a maximum near the center of the band and droop off toward the band edges.

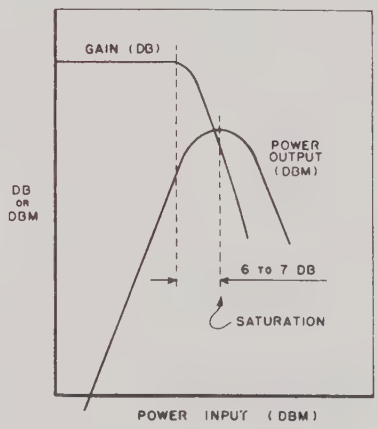


Figure 5. Gain and Power Output vs Power Input at a Fixed Frequency.

Power Output and Gain vs Power Input. Figure 5 shows the variation of power output and gain as a function of power input at a fixed frequency. The amplifier is linear until the power input is within 6 to 7 db of the value which drives the amplifier to saturation. At this point the power output curve begins to droop over, and gain of the tube begins to decrease. At saturation the power output is a maximum, and gain has decreased to the saturation gain level. As the tube is driven beyond saturation the power output drops off, and gain continues to decrease. To obtain maximum power output from an ordinary traveling-wave tube, the right amount of power input must be applied. As will be noted, the saturation region does not exhibit the leveling off or flat saturation characteristic that is found in conventional low frequency amplifier tubes.

Gain vs Beam Current and Grid Voltage. Figure 6 shows that the gain at any fixed frequency is essentially a function of the 1/3 power

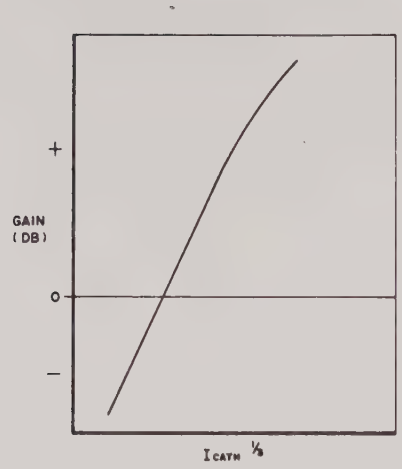


Figure 6. Gain vs Beam Current.

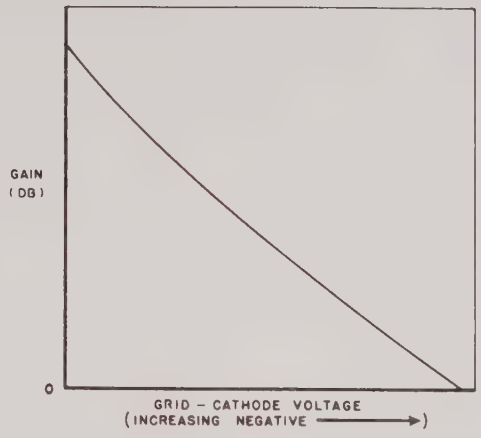


Figure 7. Gain vs Grid Voltage.

of the beam current, and as beam current decreases, gain decreases. Figure 7 shows that the gain of the tube decreases as the grid electrode is made negative with respect to the cathode. This results from the fact that operating the grid negative with respect to the cathode causes the beam current to decrease.

Should the beam current be decreased below a certain value as shown in Figure 6, the gain of the tube measured in db becomes negative, (i.e., the tube is acting as an attenuator). If the beam current is reduced to zero, the net "cold" attenuation of the tube is available. The total change in signal output level as beam current is decreased from its normal value to zero is equal to the sum of the net gain of the tube plus the cold attenuation. This can approach a variation in signal level of about 100 db. Such a change in signal output level is accomplished merely by varying the control grid voltage.

SPECIAL CHARACTERISTICS

Low Noise Amplifiers. A typical low power amplifier may exhibit a noise figure of 20 db. Certain applications require lower noise figures than this. Techniques are available in electron gun design whereby the "shot noise" in the beam can be "de-amplified" before it reaches the beginning of the helix. Special purpose tubes built in this fashion have reached noise figures as low as 6 db.

Narrow Band Amplifiers. Where an application does not require extremely wide bandwidths, tubes can be designed to operate in the dispersive region of the tube characteristic where the velocity of the waves varies as a function of frequency (see Figure 2). In this region, operation at a fixed voltage leads to amplification over only a relatively narrow band of frequencies. Extremely high values of gain (e.g., 60 to 70 db) can be obtained because the problem of controlling spurious oscillations is much simplified since the tube exhibits gain over only a relatively narrow band.

Special Gain Variation. Sometimes special requirements are imposed on the gain variation of the tube as a function of frequency. Tubes can be designed which exhibit an essentially constant value of gain across the band. Others have been built which have linearly increasing gain with frequency. Various other combinations are also possible.

MICROWAVE MEASUREMENT TECHNIQUES

L. A. Roberts *

As traveling-wave tubes come into more common use, the need becomes apparent for clarification of the various measurement techniques involved in evaluating tube characteristics. In such measurements emphasis must be placed upon broad-band, untuned measuring techniques and test equipment since the traveling-wave tube is a very broadband device. Otherwise, much time would be lost in the repetitive and laborious adjustment and tuning of narrow band devices to make point-by-point measurements across wide frequency ranges.

In this Engineering Note we will concern ourselves with the measurement of small-signal gain, power output, standing-wave ratio, insertion loss, and noise figure. Though automatic and more modern techniques may be available, the methods discussed herein will prove both useful and reliable. Further, these methods require commonly available and relatively inexpensive test equipment.

The types of broadband test equipment commonly used are:

1. Self-tracking tunable signal generator with calibrated power output.
2. Untuned coaxial crystal detector.
3. Untuned coaxial bolometer or thermistor mount with self-balancing power bridge.
4. Broadband coaxial fixed attentuator.
5. Coaxial switch (SPDT).
6. Coaxial slotted section (for VSWR measurements) with untuned detector.
7. Coaxial or waveguide directional coupler.
8. Flourescent noise source.

The emphasis on measuring equipment is placed upon coaxial systems. This is because coaxial test equipment has inherently wideband properties. Waveguide equipment is utilized only when equivalent coaxial equipment is not available or will not do an equivalent job.

SMALL-SIGNAL GAIN MEASUREMENT

A rapid and satisfactory method of measuring gain is to make an insertion gain measurement using the substitution method. This method requires no knowledge of the detector characteristics, nor is absolute power calibration of the signal generator necessary. Accuracy of the measurement depends only on the calibration accuracy of the signal generator output attenuator.

Figure 1 shows a block diagram of the small-signal gain measurement system. With the coaxial switches in position 1, the output of the sig-

* Formerly of Huggins Laboratories, Inc.

[1] For a detailed discussion of the latest swept-frequency measurement techniques using the Alfred Electronics Model 8000/7051 Sweep Network Analyzer for direct db or dbm readout over a 60-db dynamic range, refer to Alfred Electronics Application Note 101.

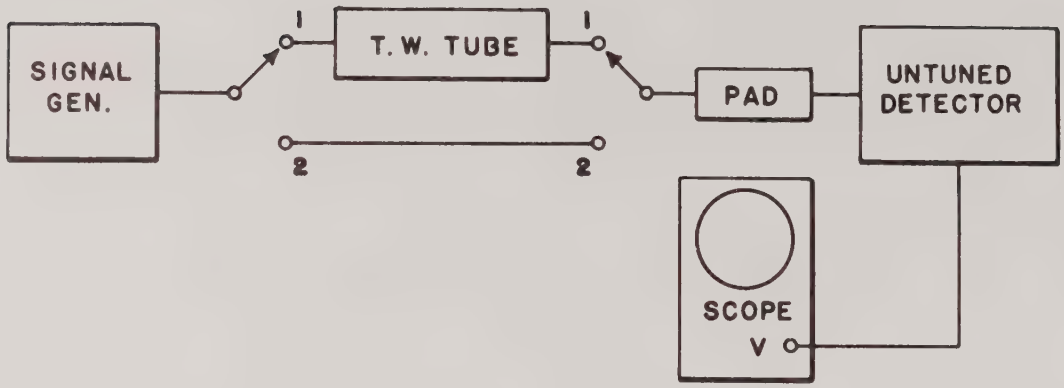


Figure 1. Block Diagram of Gain Measurement System.

nal generator (which has a matched 50 ohm output) is fed to the TWT input through a coaxial single-pole double-throw switch. The output of the TWT is in turn fed through another coaxial switch and a 6 db minimum coaxial fixed attenuator to the untuned detector (If the detector is matched to the coaxial switch, the pad can be eliminated). The detector output is then applied to the vertical deflection channel of an oscilloscope. When the switches are placed in position 2, the tube is by-passed.

Procedure. Apply pulse or square wave modulation to the signal generator. With the tube operating and the switches in position 1, the output attenuator of the signal generator is adjusted to give some convenient deflection on the scope. This is attenuator reading 1. The switches are then placed in position 2 and the attenuator readjusted to give the same deflection on the scope. This is attenuator reading 2. The insertion gain of the tube is then the difference between attenuator readings 1 and 2 measured in db.

Precautions. Both the signal generator and the detector must present good impedance matches as seen by the switch. If they are not matched, reflection losses can give up to several db error in gain. This is the reason for the pad ahead of the unmatched detector, for a 6 db pad guarantees a VSWR of at most 1.5:1.

Also, the switches used must have a low VSWR and very low crosstalk. Crosstalk is stray feedthrough from the input to output terminals of the DPST switch combination through the unused channel. The crosstalk ratio is measured with the TWT removed and is equal to the difference between the signal generator attenuator readings when it is adjusted for equal scope deflection with the switches in position 1 and 2. Regenerative feedback around the switches, which introduces errors in the gain measurement, will be prevented if the crosstalk ratio is at least 20 db greater than the gain of the tube being measured. If the crosstalk ratio exceeds 45 db, it probably cannot be measured with the system in Figure 1. The crosstalk ratio can be measured in such cases with the insertion loss measurement system soon to be described.

Further, care must be taken to insure that the output power level of the tube is at least 10 db below the saturation power level. This eliminates errors due to the decreasing gain characteristic of the traveling-wave tube in the region near saturation.

POWER OUTPUT MEASUREMENT

When making power measurements over wide frequency ranges, it is convenient to use broad-

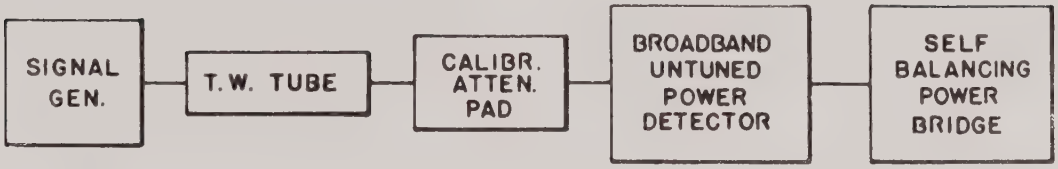


Figure 2. Block Diagram of Power Measuring System.

band (untuned) bolometer or thermistor mounts as power detectors. When these mounts are operated in conjunction with a self-balancing wattmeter bridge, they provide a convenient system for the measurement of absolute power.

If the power level to be measured is greater than the maximum allowable power input to the mount, a calibrated attenuator pad should be inserted ahead of the mount. The most convenient type of pad to use is the resistive film type which has attenuation characteristics that are essentially independent of frequency. Care must be taken not to exceed the maximum input rating of the attenuator.

If power levels to be measured are greater than the rated dissipation of standard attenuator pads, a directional coupler must be placed on the output of the tube. The main arm of the coupler is terminated with a broadband load, and the power detector, with appropriate pads, is placed in the auxiliary arm of the coupler. Broadband coaxial directional couplers with coupling ratios of 10 and 20 db from main arm to auxiliary arm are available.

Should gain measurements be made in conjunction with the power measurements, the power output of the signal generator must be calibrated using its power monitor at each frequency. For accuracy, the power output reading of the signal generator should be initially checked using the bolometer mount and the wattmeter bridge at least over the range of power levels that the bridge can accurately read. Small-signal gain measurements obtained with this equipment should check with the small-signal gain measurements made by the substitution method if the calibration of the attenuator pad and the signal generator is checked.

If all power measurements are recorded in terms of dbm (i.e., db with respect to one milliwatt), the readings of the power bridge, the attenuator (in db) and the signal generator need be merely added and subtracted to obtain power output and gain. Conveniently, most signal generators and power bridges are calibrated in dbm as well as milliwatts.

Figure 2 shows the block diagram of the power measurement system. The power output is given by the equation:

$$\text{Pout (dbm)} = \text{Pad Attenuation (db)} + \text{Ratio of Directional Coupler (db)} + \text{Power Bridge Reading (dbm)}$$

The gain of the tube is given by the equation:

$$\text{Gain (db)} = \text{Pout (dbm)} - \text{Pin from Signal Generator (dbm)}$$

The above gain measurement is valid for both small-signal gain and gain measured in the saturation region and beyond.

STANDING-WAVE RATIO OR REFLECTION COEFFICIENT MEASUREMENT

For direct measurement of voltage standing-wave ratio (VSWR), the coaxial slotted line is the

simplest method. It is essential to have an untuned detector on the slotted line, however, in order to speed up broadband measurements.

When it is necessary to examine the VSWR continuously over a wide frequency range, and where fast checks are required such as on production test setups, the slotted line type of measurement becomes prohibitively time consuming and laborious.

For such situations, the measurement of reflection coefficient through the use of directional couplers is recommended. Two directional couplers which are connected so that one gives an output proportional to the incident wave and the other an output proportional to the reflected wave from the load are used. These two outputs can be detected and compared with a ratiometer to give a direct reading of reflection coefficient. The reflection coefficient is then converted to equivalent VSWR if necessary. The greater the accuracy required in the measurement of reflection coefficient, the higher must be the directivity of the directional couplers. In waveguide, directivity greater than 40 db over the waveguide range can be obtained which allows measurement of reflection coefficient of 0.1 with an accuracy of ±.02. This means that a load VSWR of 1.2 will give an indicated reading between 1.15 and 1.25. A waveguide to coaxial transition can be used to adapt the reflectometer to coaxial systems, but residual reflection in the transition limits the accuracy at low VSWRs.

Once the initial calibration is performed in such a reflectometer system, it is only necessary to tune the signal generator across the frequency range and read the reflection coefficient values directly. An excellent detailed discussion of this method, its errors and limitations, is given in the Hewlett-Packard Journal, Volume 6, Number 1-2, Sept. - Oct., 1954.

Even faster measurements can be made when a swept oscillator is employed. Reflection coefficient can be displayed directly on a scope as a function of frequency, and the measurement can be made at a glance.

INSERTION LOSS MEASUREMENT

Measurement of insertion loss in the range of 40 to 100 db (e.g., cold loss measurement in a traveling-wave tube) over a wide range of frequencies is not uncommon. Such a measurement cannot be made with a 1 milliwatt signal generator and a broadband detector, for this type of system does not have the power levels, nor the sensitivity, to measure much more than 45 db insertion loss.

Wideband measurements can be made quickly and easily, however, with the use of one or two traveling-wave tubes as amplifiers. Use of a traveling-wave tube with a noise figure of 20 db ahead of the detector gives a sensitivity into a broadband detector on the order of −65 to −75 dbm. This alone allows insertion loss measurements of 65 to 75 db. Further, if the output of the signal generator is amplified to the power level of one watt (+ 30 dbm) by using a medium power traveling-wave tube, the total insertion loss then measurable becomes 95 to 105 db.

Since traveling-wave tubes are broadband, untuned devices, the only adjustment necessary in this system as frequency is changed across the band is the tuning of the signal generator. The insertion loss measurement is made in the same manner as the insertion gain measurement shown in Figure 1 except for the addition of the amplifiers before and after the switches. Commercially available switches, when connected as shown in Figure 1, have been measured which have a combined crosstalk ratio in excess of 120 db This, of course, eliminates any crosstalk error in insertion loss measurements in the range of 95 to 105 db.

NOISE FIGURE MEASUREMENT

When one is interested in measuring noise

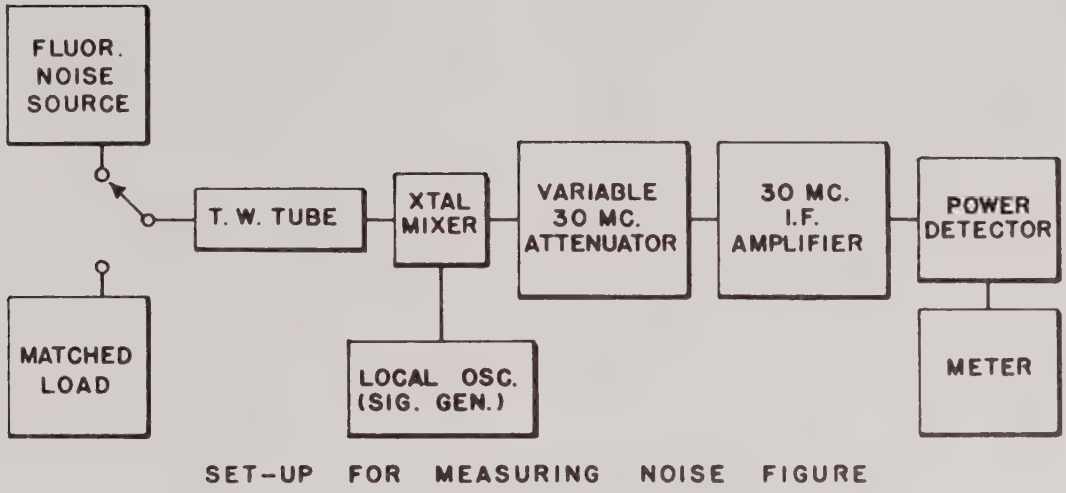


Figure 3. System for Measuring Noise Figure.

figure at a number of frequencies over a wide frequency band, a system which employs a fluorescent tube noise source and a superheterodyne receiver with a square-law second detector (i.e., a power detector) can be used. If noise figure does not vary too rapidly with frequency, a simple receiver can be used which employs an untuned crystal mixer, a local oscillator, a 30 mc IF strip, and a power detector. Note that no preselection or mixer tuning is used.

Without a preselector, the receiver will respond equally well to both the signal and image frequencies. With a 30 mc IF amplifier, these two frequencies will be only 60 mc apart. The measured noise figure will be an average of the true values at two frequencies 60 mc apart providing noise figure is not a rapid function of frequency. This is accurate enough for most purposes. If noise figure varies so rapidly that it will be appreciably different at two frequencies spaced 60 mc apart, then preselection is necessary.

The noise figure of an amplifier is defined as the ratio of the signal-to-noise ratio at the input of the amplifier to the signal-to-noise ratio at the output of the amplifier, That is,

$$F = \frac{(S/N)in}{(S/N)out} \qquad \text{(power ratio)}$$

When the measurement is made according to the method to be outlined, and a noise source whose level is 15.8 db above thermal noise is used, the above equation becomes:

$$F = \frac{37k}{\frac{P_1}{P_2} - 1} \qquad \text{(power ratio)} \qquad (1)$$

where, P_1 and P_2 are as defined in the measurement procedure below, and k, a number smaller than 1.0, is the cable loss in db between the noise source and the tube converted to a power ratio. (e.g.) for cable loss = 1db, k = .794)

When a fluorescent noise source is used, it is not necessary to know the effective RF noise bandwidth of the receiver.

Procedure: The tube to be measured is connected into the system shown in Figure 3. The

power detector in the receiver may take the form of a bolometer or a thermistor operating into a self-balancing wattmeter bridge, or it may be a thermocouple whose output is connected to a microammeter.

With the TWT operating and the local oscillator tuned to the desired frequency, switch the tube input to the noise source. Adjust the variable 30 mc attenuator until the output meter indicates approximately full scale. This is reading P_1.

Then switch the tube input to the matched load. The output meter now indicates P_2. Insert the values of P_1 and P_2 in equation 1 and compute the noise figure. To determine the noise figure in db, merely convert this number to db.

Precautions: The accuracy of this measurement is based on the assumption that the receiver is linear. This will be true if the local oscillator signal is large enough to produce linear mixing and if the IF amplifier is operated in the linear portion of its characteristics

The measurements should be taken quickly enough so that power meter drift will not affect readings.

ALFRED

Tube Warranty and Replacement Procedure

TUBE REPLACEMENT

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS for either warranty or out-of-warranty replacements. Current prices are given on the Replacement Tube Price List.

TUBE WARRANTY

The following warranties are applicable to tubes used in catalog instruments only. For the warranty applicable to tubes used or for use in special or modified instruments, please check with the factory. All tube warranties are from date of shipment by ALFRED.

WARRANTY FOR TWT AND VTM

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C) or one-year time period, whichever results in lesser credit.

Warranty Condition*	Tube Type	Applicable Tube Group or Alfred Tube Part No. Series	A Mo.	B Hours	C Hours
WC2	VTM	112-001 and 112-003	2	100	1000
WC3	TWT	10 and 20 mw output except WC4 tubes	12	500	2000
WC4	TWT	112-040 and 112-047	12	2000	-
WC5	TWT	1 watt output except WC6 and WC7 tubes	12	1500	-
WC6	TWT	112-046, 112-065, & 112-072	12	1000	-
WC7	TWT	112-057, 112-080, & 112-081	12	250	1000
WC8	TWT	2 to 10 watt output except WC9 tubes	12	75	500
WC9	TWT	112-055	2	50	500

* WC# denotes the corresponding warranty period(s) shown in the right-hand column(s) and is used for cross-reference to this warranty statement from other documents.

WARRANTY FOR ALL BWO TUBES

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown below, without regard to the number of heater hours used.

Warranty Condition*	Tube Type	Warranty
WC10	BWO	Warranted unconditionally for one (1) year.

WARRANTY CONDITIONS APPLY ONLY TO TUBES LISTED ABOVE WHICH ARE USED IN ALFRED CATALOG INSTRUMENTS.

This warranty applies only to tubes sold after July 1, 1969.

TUBE SERVICE REPORT

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

RETURN PROCEDURE

In case a tube or instrument fails, please contact the factory or your local sales representative for advice or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods.

Use similar wrapping, packing and shipping provisions for an instrument. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

IN-WARRANTY FAILURE - BWO AND VTM TUBES

BWO and VTM tubes which fail in warranty will be replaced with a new tube. In case a tube fails, please issue a purchase order for a new tube at the tube list price and return the defective tube. Warranty credit will be issued and deducted from the price, subject to tube manufacturer's verification that failure was caused by tube malfunction. To qualify for maximum credit, it is essential that the defective tube be properly packed and returned within 30 days after failure.

REPAIRABLE OR IN-WARRANTY FAILURE - TW TUBES

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

WARRANTY CREDIT

Any applicable credit allowed under the terms of this warranty applies only toward the purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of six (6) months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF CABLES

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge. For prices see Replacement Tube Price List.

SPECIAL CONDITIONS

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions, lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

8/1/69

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

_____

1. Was operation normal just prior to failure? Yes _____ No _____
2. If not, what was done to adjust it? _____

_____

_____

3. Has proper cooling been maintained during tube operation? _____

_____

4. Did helix overcurrent tripout occur? _____

_____

5. Was environment normal? (specify) _____

_____

6. Symptoms - (describe failure) _____

_____

_____

7. Operating conditions at time of failure (indicate any unusual conditions) _____

_____

_____

8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

SHIPMENT DAMAGE CLAIM

The instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim must be filed with the carrier. Have carrier agent inspect damage to instrument and packing crate and forward us a copy of his written report. You will then be advised of replacement or repair arrangements and disposition of the equipment. Please include model number, type number and serial number when referring to this instrument for any reason.

WARRANTY

ALFRED products are warranted against defects in workmanship and materials. This warranty is limited to repair or replacement of products or parts (except tubes, transistors, and batteries) which prove defective within one year after delivery to original purchaser. ALFRED ELECTRONICS is not liable for consequential damage.

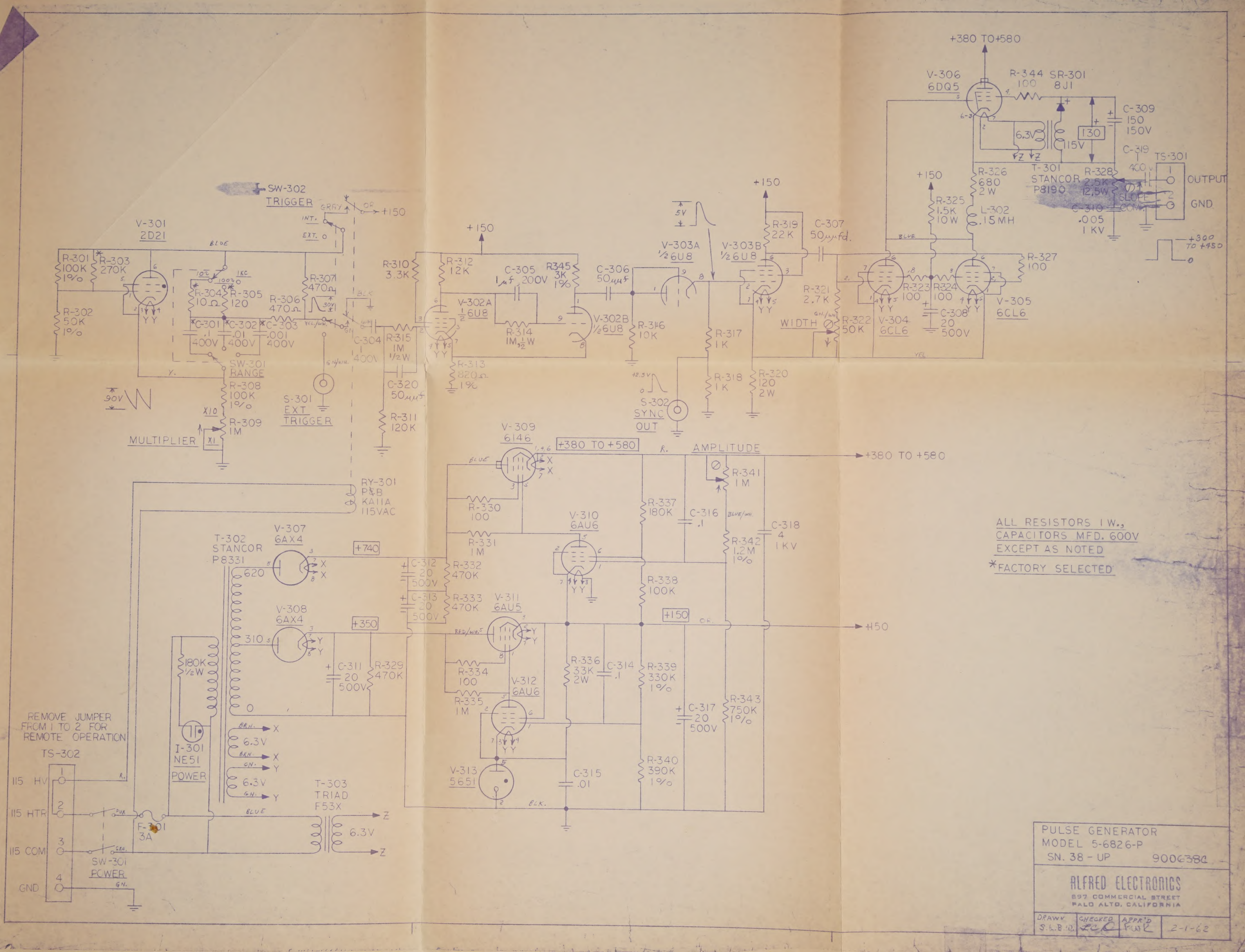
If any fault develops:

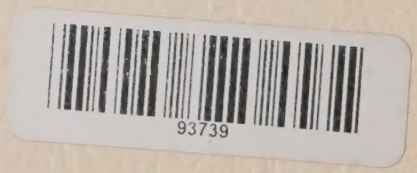
1. Notify us, giving full details of the difficulty, including the model number, type number and serial number. Upon receipt of this information, you will be sent service instructions or shipping data.

2. Upon receipt of shipping instructions, forward the instrument prepaid and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins when instrument is not covered by this warranty.

PACKING

The instrument should be packed in the original carton. If unusable or not available, use a wooden box with approximately three inches of excelsior or other shock-absorbing material surrounding the instrument. If desired, packing services of a local transfer and storage company may be employed.


SW-302 TRIGGER
GRAY
OR
+150
INT.
EXT.
V-301 2D21
BLUE
R-301 100K 1%
R-303 270K
R-302 50K 1%
10Ω
100Ω
1KC
R-304 10Ω
R-305 120
R-306 470Ω
R-307 470Ω
30V
C-301 .1 400V
C-302 .01 400V
C-303 .001 400V
SW-301 RANGE
90V
X10
X1
R-308 100K 1%
R-309 1M
MULTIPLIER
S-301 EXT TRIGGER
C-304 1 400V
R-315 1M 1/2W
C-320 50μμf
R-311 120K
R-310 3.3K
R-312 12K
C-305 1μf 200V
R345 3K 1%
V-302A 1/2 6U8
R-314 1M 1/2W
V-302B 1/2 6U8
C-306 50μμf
R-313 820Ω 1%
+150
5V
V-303A 1/2 6U8
V-303B 1/2 6U8
R-319 22K
C-307 50μμfd.
R-316 10K
R-317 1K
R-318 1K
R-320 120 2W
12.5V
S-302 SYNC OUT
WIDTH
R-321 2.7K
R-322 50K
R-323 100
R-324 100
C-308 20 500V
V-304 6CL6
V-305 6CL6
R-327 100
R-325 1.5K 10W
L-302 .15MH
R-326 680 2W
+380 TO+580
V-306 6DQ5
R-344 100
SR-301 8J1
C-309 150 150V
6.3V
115V
130
T-301 STANCOR P8190
C-319 400V
R-328 2.5K 12.5W
C-310 .005 1 KV
TS-301
OUTPUT
GND
SLOPE
COMM.
+300 TO +450
V-309 6146
+380 TO +580
R. AMPLITUDE
+380 TO +580
R-330 100
R-331 1M
V-310 6AU6
R-337 180K
C-316 .1
R-341 1M
R-342 1.2M 1%
C-318 4 1KV
R-338 100K
+150
OR.
+150
R-332 470K
C-312 20 500V
R-333 470K
C-313 20 500V
V-311 6AU5
R-334 100
R-335 1M
V-312 6AU6
R-336 33K 2W
C-314 .1
R-339 330K 1%
C-317 20 500V
R-343 750K 1%
R-340 390K 1%
V-313 5651
C-315 .01
+150
RY-301 P&B KA11A 115VAC
V-307 6AX4
T-302 STANCOR P8331
+740
620
V-308 6AX4
+350
310
180K 1/2W
C-311 20 500V
R-329 470K
I-301 NE51 POWER
BRN.
6.3V
GN.
BLUE
T-303 TRIAD F53X
6.3V
REMOVE JUMPER FROM 1 TO 2 FOR REMOTE OPERATION
TS-302
115 HV
115 HTR
115 COM
GND
PUR.
GRA.
SW-301 POWER
F-301 3A
ALL RESISTORS 1W., CAPACITORS MFD. 600V EXCEPT AS NOTED
*FACTORY SELECTED
PULSE GENERATOR
MODEL 5-6826-P
SN. 38 - UP
9006380
ALFRED ELECTRONICS
697 COMMERCIAL STREET
PALO ALTO, CALIFORNIA
DRAWN S.L.B.
CHECKED
APPR'D
2-1-62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